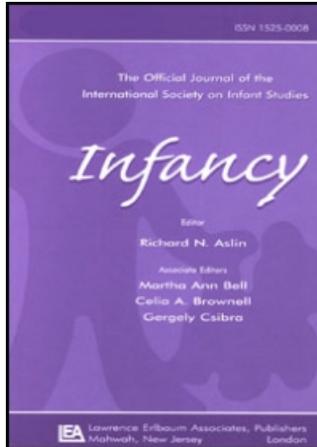


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# Sex Differences in Infants' Ability to Represent Complex Event Sequences

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Prior research suggests that when very simple event sequences are used, 4.5-month-olds demonstrate the ability to individuate objects based on the continuity or disruption of their speed of motion (Wilcox & Schweinle, 2003). However, infants demonstrate their ability to individuate objects in an event-monitoring task (i.e., infants must keep track of an ongoing event) at a younger age than in an event-mapping task (i.e., infants must compare information from 2 different events). The research presented here built on these findings by examining infants' capacity to succeed on an event-mapping task with a more complex event sequence to determine if the complexity of the event interferes with their ability to form summary representations of the event, and, in short, individuate the objects. Three experiments were conducted with infants 4.5 to 9.5 months of age. The results indicated that (a) increasing the complexity of the objects' trajectories adversely affected infants' performance on the task, and (b) boys were more likely to succeed than girls. These findings shed light on how representational capacities change during the first year of life and are discussed in terms of information processing and representational capabilities as well as neuro-anatomical development.

The visual world is dynamic and complex. Farther surfaces are occluded by nearer surfaces and these relations change as the surfaces, or the observer, move about in the world. One of the primary tasks of visual cognition is to form representations

of distinct objects that persist through these changes. Over the last 10 years the problem of object individuation—determining whether an object that moves into view is the same object or a different object than the one that disappeared earlier—has received a great deal of attention from infant researchers (e.g., Aguiar & Baillargeon, 2002; Leslie, Xu, Tremoulet, & Scholl, 1998; Spelke, Kestenbaum, Simons, & Wein, 1995; Tremoulet, Leslie, & Hall, 2001; Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Chapa, 2002, 2004; Wilcox & Schweinle, 2002, 2003; Xu & Carey, 1996). Most of this research has focused on developmental changes in infants' capacity to individuate objects in occlusion events. The outcome of this research has made clear that the question of when infants demonstrate the capacity to individuate objects cannot be answered unequivocally; it often depends on the task used. As a result, many researchers have shifted their attention to the question of under what conditions infants demonstrate successful performance. This approach has allowed researchers to identify processes that support object individuation in the infant.

### EVENT-MONITORING AND EVENT-MAPPING TASKS

Wilcox and Baillargeon (1998a) made the distinction between two kinds of object individuation tasks, event-monitoring and event-mapping, and suggested that these two tasks differ in the information processing demands they impose. In event-monitoring tasks, infants are shown an occlusion event in which one or two objects emerge successively to each side of a screen. Infants must monitor whether successive portions of the event are consistent (e.g., whether the screen is sufficiently wide to hide the objects involved). In event-mapping tasks, infants also see an occlusion event involving one or two objects, but then the screen is removed and infants see a final display containing either one or two objects. Hence, whereas infants see only one kind of event (i.e., an occlusion event) in event-monitoring tasks, they see two categorically distinct events (i.e., an occlusion event followed by a nonocclusion event) in event-mapping tasks. Wilcox and Baillargeon argued that tasks involving categorically distinct events place relatively high information processing demands on infants. First, when presented with two different physical situations, infants must set up two separate event representations: The change in event category, from occlusion to nonocclusion, leads infants to establish a new event representation (see Wilcox & Chapa, 2002). Second, in the interest of making sense of these two independent situations, infants must form a link between them. This linking, or mapping, process requires that infants (a) retrieve their representation of the first event, (b) compare it to their representation of the second event, and (c) determine whether the two are consistent.

Given the difference in information processing demands, it is not surprising that infants are more likely to succeed on event-monitoring than event-mapping tasks.

For example, infants as young as 4.5 months demonstrate the capacity to individuate objects on the basis of featural differences when an event-monitoring task is used (Wilcox, 1999; Wilcox & Baillargeon, 1998b), yet it is not until 5.5 months that infants succeed when an event-mapping task is used (Wilcox & Schweinle, 2002). Likewise, 3.5-month-olds demonstrate the capacity to individuate objects based on discontinuities in speed of motion when an event-monitoring task is used, yet it is not until 4.5 months that infants succeed when an event-mapping task is used (Wilcox & Schweinle, 2003). It is, as yet, unclear what part of the mapping process causes young infants so much difficulty.

### EVENT-MAPPING RESULTS: FEATURAL INFORMATION

One way to address the question of what makes event mapping so difficult is to identify factors that influence infants' performance on event-mapping tasks. One factor that is known to influence mapping performance is event complexity. There is evidence that if the occlusion sequence to be mapped is very simple (i.e., if the objects follow a single, nonreversing trajectory), infants are more likely to succeed than if the occlusion sequence is more complex (i.e., if the objects follow multiple, reversing trajectories). For example, in one experiment (Wilcox & Schweinle, 2002) 5.5-month-olds were tested using a simple (i.e., single-trajectory) event-mapping task. Infants were assigned to one of two conditions: egg-column or column-column. In the initial phase of the test event, infants saw an egg (egg-column condition) or a column (column-column condition) disappear behind the left edge of a wide screen and, after an appropriate interval, a column appeared from behind the right edge. Then the screen was lowered to the apparatus floor, marking a change in event category (from occlusion to nonocclusion). In the final phase of the test event, infants saw only the column to the right of the screen (the area behind the lowered screen was empty). The infants in the egg-column condition looked reliably longer at the final one-column display than the infants in the column-column condition, suggesting that the infants (a) perceived that the egg-column event involved two objects and the column-column event involved only one object; (b) found their representation of the egg-column event (but not the column-column event) inconsistent with the final one-column display; and (c) responded with prolonged looking in the egg-column condition. This interpretation was supported by data obtained in two control conditions that were identical to the experimental conditions except that a second screen occluded the area behind the lowered screen in the final display (i.e., infants were not shown the number of objects behind the screen). In the control experiment, infants in the egg-column and column-column conditions looked about equally at the one-column display. Similar results (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002) have been

obtained with 7.5- and 9-month-olds using these and other featurally distinct objects.

In contrast, when infants are tested using a complex (i.e., multiple-trajectory) event-mapping task, they are less likely to evidence success. For example, in an experiment conducted by Wilcox and Baillargeon (1998a), 9.5-month-olds were assigned to either a ball–box or a ball–ball condition. In the ball–box condition, infants saw a ball disappear behind the left edge of a wide screen and a box appear at the right edge. The box stopped, returned behind the screen, and the ball reappeared at the left edge. Next, the entire event cycle repeated. Finally, the ball returned behind the screen and the screen was lowered. Hence, each object underwent several reversals during the occlusion sequence. (In Wilcox & Schweinle, 2002, the objects never changed trajectory.) In the final phase, infants saw a single ball sitting behind the lowered screen. The infants in the ball–ball condition saw a test event similar to those in the ball–box condition, except that a ball rather than a box was seen to the right of the screen. The infants in the ball–box and ball–ball conditions looked about equally at the one-ball display, as if they had failed to detect the inconsistency between the ball–box event and the one-ball display. It was not until 11.5 months that infants successfully mapped a complex occlusion sequence involving featurally distinct objects (i.e., events in which objects that differ in features become occluded then unoccluded) onto a nonocclusion display (for supporting evidence, see Wilcox, 2004; Xu & Carey, 1996).

Why do infants fail on multiple-trajectory event-mapping tasks? Successful event mapping requires infants to retrieve a clear, concise representation of the occlusion sequence and then compare that representation to the final display. When the sequence is short and simple, this task is relatively easy: Infants simply scan their representation of the first event to determine what objects were involved, and then align those objects with the objects in the second event. When the sequence is long and complex, this task becomes more difficult. Rather than attempt to retrieve the entire event from beginning to end, which is problematic for young infants with limited information processing capacities, infants instead attempt to retrieve a summary representation of the first event. Summary representations, in theory, can take on many different forms (e.g., dynamic visual images, static visual images, linguistic forms). However, young infants' summary representations are most likely composed of visual images.<sup>1</sup> To form a summary representation of this kind, infants must extract the simple structure of the event, which includes the most basic components of the event. For occlusion sequences, like the ball–box event, this would include information about the number of objects involved and their paths of motion (Wilcox & Baillargeon, 1998a; Wilcox, Schweinle, & Chapa, 2003). Ex-

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<sup>1</sup>Once infants have labels for objects they have the tools necessary to summarize the event in a linguistic format (e.g., Xu, 2002).

tracting the simple structure may be difficult for young infants when the event involves multiple objects and multiple trajectories.

Perhaps even more intriguing is that male and female infants differ in their capacity for mapping complex occlusion sequences. Wilcox (2004) observed that whereas both boys and girls can successfully map the multiple-trajectory ball–box sequence previously described at 11.5 months, only boys succeed at 10.5 months (both boys and girls fail at 9.5 months). Furthermore, if allowed to view an “outline” of the box–ball event prior to the test trials, 7.5-month-old infants' performance improved (Wilcox, 2003). However, the girls needed more information in the outline than did boys. Why are boys more likely to succeed at mapping complex occlusion sequences than girls? Recent results obtained by Wilcox (2003, 2004) suggest that one explanation for these sex differences is that boys are better able to extract the simple structure of occlusion sequences than girls. In the repeating ball–box event the simple structure would be the following: One object (i.e., the box) moves to the left of the screen and a second object (i.e., the ball) moves to the right.

To summarize, event-mapping experiments have revealed two main findings: (a) infants are more likely to succeed when the objects follow a single, non-reversing trajectory than when the objects follow multiple, reversing trajectories; and (b) boys are more likely than girls to succeed at mapping events involving multiple, reversing trajectories. One limitation of these results, however, is that they were all obtained with occlusion sequences containing two featurally distinct objects (e.g., an egg and a column or a ball and a box). Hence, the objects could be individuated only on the basis of featural differences. Furthermore, when forming a summary representation of the event, each featurally distinct object would need to be bound to its respective trajectory. Because it is easier for infants to individuate objects based on spatiotemporal than featural criteria (Aguiar & Baillargeon, 2002; Spelke et al., 1995; Wilcox & Schweinle, 2002, 2003; Xu & Carey, 1996), and it is easier for infants to build event representations when they are not required to bind specific objects to trajectories (e.g., the same object appeared on both sides of the screen; Wilcox & Schweinle, 2002), one might wonder whether the same pattern of results would be obtained if (a) the objects could be individuated on the basis of spatiotemporal information, and (b) the objects were identical in appearance.

#### EVENT-MAPPING RESULTS: SPATIOTEMPORAL INFORMATION

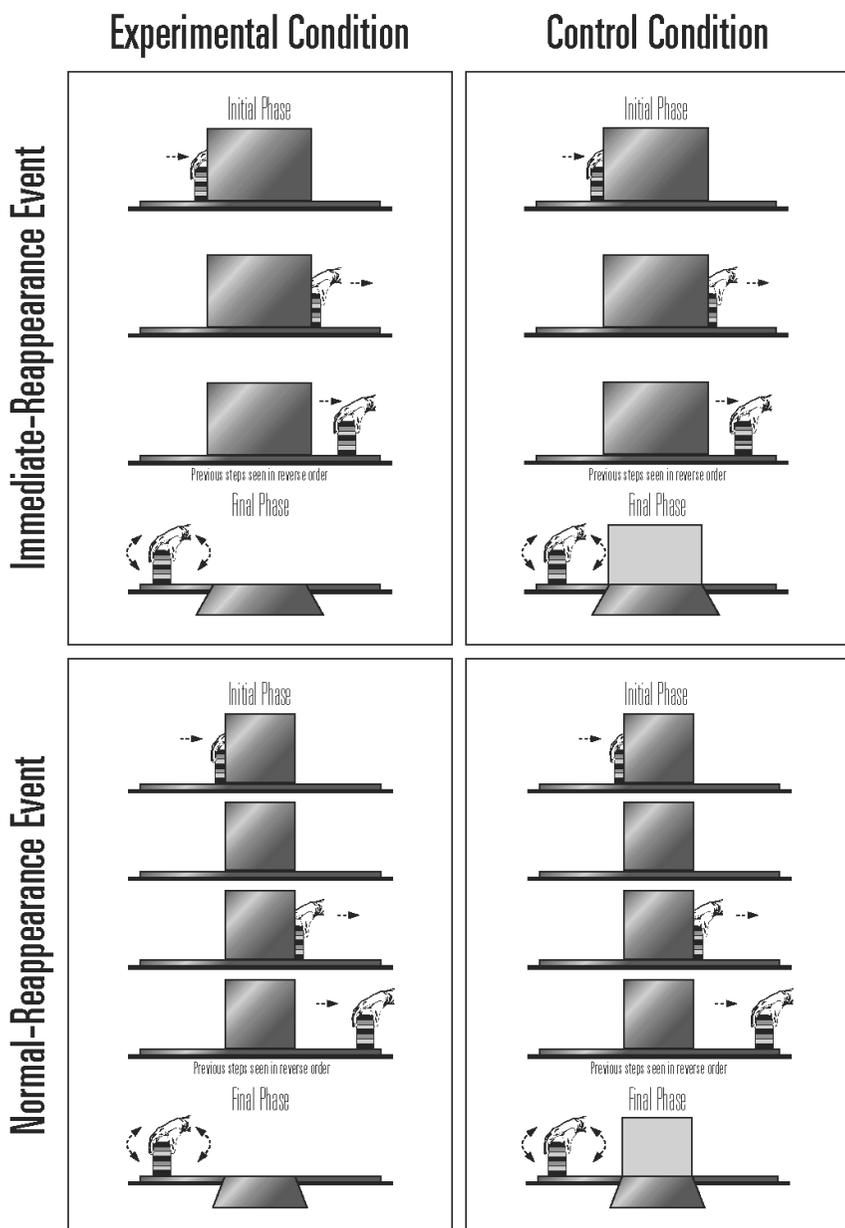
Wilcox and Schweinle (2003) recently investigated young infants' capacity to individuate featurally identical objects based on spatiotemporal information using a one-trajectory event-mapping task. Infants 4.5 and 7.5 months old were shown one

of two events: immediate or normal reappearance. In the immediate reappearance event, in the initial (occlusion) phase, a column disappeared behind the left edge of a wide screen and immediately reappeared at the right edge; the screen was then lowered. In the final (nonocclusion phase), the infants saw one column sitting to the right of the screen. The normal reappearance event was similar to the immediate reappearance event except that the column was occluded for an interval appropriate for its rate of motion. The 4.5- and 7.5-month-olds who saw the immediate reappearance event looked reliably longer at the one-column display than those who saw the normal reappearance event, suggesting that the infants (a) perceived that the immediate reappearance event involved two columns and the normal reappearance event involved one column, and (b) were successful at mapping the immediate reappearance event onto the final one-column display. Because it could be argued that the infants simply found the final display more novel or interesting following the immediate rather than the normal reappearance event, control conditions were added in which infants saw the immediate or normal reappearance event with one difference: A second screen stood behind the lowered screen in the final phase. The second screen was sufficiently tall to hide a second column. In the control condition, the infants who saw the two events looked about equally during the final phase of the test event, demonstrating no preference for the final display following either the immediate or the normal reappearance event.

These results raise two questions. First, how would 4.5- and 7.5-month-olds perform if the immediate reappearance event was made more complex by adding a reversal to the trajectories of each object? If the event-mapping difficulties observed by Wilcox (2003, 2004) reflect general limitations in information processing capacities, then infants should evidence greater difficulty mapping a two-trajectory than one-trajectory discontinuous-speed event. In contrast, if the problem is specific to events involving featurally distinct objects, then the complexity of the objects' trajectories should not influence infants' capacity to map the discontinuous-speed event. Second, would boys and girls perform differently? If sex differences were obtained in yet another multiple-trajectory task, it would support the idea that there are sexually dimorphic differences in infants' capacity to map complex occlusion sequences.

## THIS RESEARCH

The research reported here assessed the extent to which event complexity and sex would influence infants' capacity to map a discontinuous-speed event. Infants saw the immediate or normal reappearance event of Wilcox and Schweinle (2002) with the following modification: Once the column reached the right edge of the platform it stopped, reversed direction, and the immediate or normal reappearance event was seen in reverse (Figure 1). Finally, the screen was lowered and infants



**FIGURE 1** Schematic drawing of the test events shown to the infants in Experiments 1 through 3. The 4.5-month-olds in Experiment 1 saw the experimental immediate or normal reappearance event (displayed in the left column). The 7.5- and 9.5-month-olds in Experiments 2 and 3 saw one of the four test events formed by crossing test event (immediate or normal) and condition (experimental or control).

saw one column sitting to the left of the lowered screen. Three separate experiments were conducted with infants 4.5 to 9.5 months old using the two-trajectory event-mapping task.

## EXPERIMENT 1

In Wilcox and Schweinle (2003), 4.5-month-olds successfully mapped a single-trajectory discontinuous-speed event onto a one-object display. Experiment 1 examined 4.5-month-olds' ability to map a two-trajectory discontinuous-speed occlusion event onto a similar display. Infants were assigned to one of two conditions: immediate or normal reappearance. Infants saw the two-trajectory immediate or normal reappearance event described previously (Figure 1). If making the objects' trajectories more complex by adding a reversal in direction impairs infants' ability to retrieve a clear, coherent representation of a discontinuous-speed event, then the infants in the immediate and normal reappearance condition should look about equally at the one-column display. In contrast, if 4.5-month-olds' ability to map a discontinuous-speed event is robust to trajectory changes, then this manipulation should not interfere with mapping performance.

### Method

#### *Participants*

Participants were 32 infants (16 boys and 16 girls) who were 4.5 months old ( $M = 4$  months, 20 days; range = 4 months, 13 days–5 months, 4 days). This is the age range of the 4.5-month-olds tested in Wilcox and Schweinle (2003). In this and all subsequent experiments infants were healthy and born full-term. An additional 7 infants were eliminated from the analyses: 3 because of procedural problems, 1 due to distraction by a sibling, and 3 because the infant failed to look during the initial phase of the test event. Sixteen infants (8 boys and 8 girls) were randomly assigned (with the stipulation that an equal number of boys and girls were included in each group) to the immediate reappearance ( $M = 4$  months, 20 days) or normal reappearance ( $M = 4$  months, 22 days) conditions.

#### *Apparatus*

The apparatus was a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. The infant sat facing an opening 51 cm high and 93 cm wide in the front wall of the apparatus. The floor of the apparatus was covered with cream-colored contact paper and the side walls were painted off-white. The back wall was covered with wood-grain contact paper. A 14-cm-square hole in the back wall, centered between the right and left walls and flush with the floor, was concealed with a remov-

able door also covered with wood-grain contact paper. A platform, 1.5 cm high, 91 cm wide, and 20 cm deep, covered with cream contact paper, lay centered between the left and right walls and flush with the back wall. A 12.5-cm-deep strip of light blue flannel lay centered down the length of the platform.

The two columns, which were identical in appearance, were made of alternating rows of red, yellow, and blue Duplos and were 12 cm high, 6 cm wide, and 3 cm deep. They were mounted on a piece of Plexiglas 0.3 cm high, 6 cm wide, and 3 cm deep.

The screen used in the immediate reappearance condition was 24 cm high and 35 cm wide. The screen was mounted in two metal clips attached to a wooden dowel; the ends of the dowel exited the apparatus through small holes in the right and left walls. By rotating the dowel's right end (out of the infant's view), the screen could be lowered to lay flat on the apparatus floor. The screen used in the normal reappearance condition was 24 cm high and 24 cm wide and could be manipulated in the same fashion as the immediate reappearance screen. Both screens were made of cardboard and covered with dark green contact paper.

A muslin-covered curtain was lowered after each trial to cover the opening in the front wall of the apparatus. Two muslin-covered frames, each 213 cm high and 68 cm wide, stood at an angle on either side of the apparatus; these frames isolated the infant from the experimental room. In addition to the room lighting, four 20-watt fluorescent bulbs (60 cm long in front and back and 30 cm long on each side) were attached to the inside walls of the apparatus.

### *Events*

Three experimenters worked together to produce the events. The first two experimenters wore white elbow-length gloves on their right hands and manipulated the objects. A third experimenter operated the rotating screen and the muslin-covered curtain. All three experimenters followed a precise script, using a metronome that ticked softly once per second. The numbers in parentheses indicate the time taken to produce the actions described. Prior to the experiment, the first experimenter showed the infant her gloved hand.

*Immediate reappearance.* The infants first received two pretest trials designed to acquaint them with the apparatus and objects. At the start of the first pretest trial, the rotating screen stood upright at the center of the platform. The first experimenter held the first column from the top with her right hand (making sure that no fingers obstructed the view of the object), with its center 6 cm from the left edge of the screen. She tilted it gently to the left and to the right (once to each side per second) until the trial ended. In the second pretest trial, the first experimenter held the second column, which was identical in appearance to the first column, to the right of the screen and tilted it gently until the end of the trial.

At the start of the test trial, the first experimenter tilted the first column gently to the left and right, as before. The second experimenter held the second column with her right hand behind the right half of the screen, out of the infant's view. When the computer signaled that the infant had looked at the display for 2 cumulative sec, the initial phase of the test event began. The first experimenter held the column upright (1 sec), and then moved it to the right at a rate of 3 cm per second until it was fully occluded by the screen (2.5 sec). After the first column became fully occluded, the second experimenter immediately moved the second column from behind the right edge of the screen (the two experimenters had similar-sized hands covered by identical white gloves) until its center was 6 cm from the right edge of the screen (2.5 sec). The second experimenter paused (1 sec), and then the events of the previous 5 sec were repeated in reverse.<sup>2</sup> Next, the first experimenter gently tilted the first column, which was now at its starting position, while the second experimenter surreptitiously removed the second column from behind the screen (2 sec) and the third experimenter lowered the screen (1 sec). During the final phase, the first experimenter gently tilted the column to the left of the screen; the area behind the screen was empty.

During the initial phase of the experiment, the total length of the two columns' trajectory from left to right was 47 cm, and the occlusion time was less than 0.5 sec.

*Normal reappearance.* In creating the normal reappearance event, we wanted the duration of the event cycle in the initial phase to be the same as in the immediate reappearance event (12 sec), and for the total visible motion of the objects to be as similar as possible. If we had used the same speed of motion and the same screen as in the immediate reappearance event, then the whole event cycle would have been much longer and the columns would have remained out of view for 9.7 sec each time they were behind the screen. Hence, the infants in the normal reappearance conditions saw the same pretest and test events as the infants in the immediate reappearance conditions with the following exceptions: (a) the columns traveled at a rate of 12 cm per second, (b) the test screen was replaced by the more narrow screen, and (c) the occlusion interval was appropriate for a constant rate of motion. Because the columns moved more quickly when in view, it was also necessary to increase the length of each column's trajectory. At the start of each trial the left column stood with its center 18 cm from the left edge of the screen.

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<sup>2</sup>In the immediate reappearance event the object actually increased its speed slightly as it became occluded and disoccluded. For example, the object traveled a distance of 3 cm in 0.5 sec when at each edge of the screen (i.e., it took the 6-cm-wide object 0.5 sec to go from being 50% occluded to fully occluded and 0.5 sec to go from fully occluded to 50% disoccluded). Informal reports by adult viewers indicated that the immediate reappearance event was more pronounced with this alteration, even though the observers were unable to detect the slight change in the objects' speed at each edge of the screen.

During the initial phase of the test event, the length of one trajectory across the stage was 60 cm, and the occlusion time was 1.5 sec per trajectory.

### *Procedure*

Each infant sat on a parent's lap centered in front of the apparatus; the infant's head was approximately 80 cm from the platform. Parents were instructed not to interact with their infant and to keep their eyes closed while the experiment was in progress.

The infants received two pretest trials followed by one test trial. The pretest trials ended when the infant either (a) looked at the display for a maximum of 60 cumulative sec, or (b) looked away for 2 consecutive sec after looking a minimum of 4 cumulative sec. This ensured that the infant received adequate familiarization to the test situation.

Looking times to the initial and final phases of the test trial were recorded separately. The final phase of the test trial ended when the infant either (a) looked at the display for a maximum of 60 cumulative sec, or (b) looked away for 1 sec after looking a minimum of 5 cumulative sec.

To ensure that the experimenters followed the events' scripts precisely during the pretest and test trials, a camera was placed directly behind and above the parent's head, providing a head-on view of the event as it occurred. The three experimenters monitored the event on a video screen located slightly behind and to the left of the apparatus. If a procedural error occurred (e.g., the second object emerged before the first object became fully occluded or the second object failed to appear immediately), that infant's data were eliminated from the analysis.

The infant's looking behavior was monitored by two observers who watched the infant through dime-sized peepholes in the cloth-covered frames on either side of the apparatus. The observers were not told, could not see, and were unable to guess which event each infant saw.<sup>3</sup> Each observer held a button connected to a computer and depressed the button when the infant attended to the events. The looking times recorded by the primary observer determined when a trial ended and were used in the data analyses. Each trial was divided into 100-msec intervals, and the computer determined in each interval whether the two observers agreed on the direction of the infant's gaze. Interobserver agreement was measured for 29 of the 32 infants (for the other infants only one observer was present) and was calculated for the test trial by dividing the number of intervals in which the computer regis-

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<sup>3</sup>The infants in Experiments 1 through 3 were presented with test events in which the column reappeared immediately or after an appropriate interval. At the end of each test session, the primary observer was asked to guess if the infants had seen an immediate or a normal reappearance event. Only 54 of the 112 observers reporting (12 observers failed to report) were able to correctly guess the type of test event. The cumulative binomial was not significant ( $p > .05$ ).

tered agreement by the total number of intervals in the trial. Agreement averaged 94.86% per infant.

## Results

### *Pretest Trials*

The infants' looking times during the two pretest trials were averaged and analyzed via an analysis of variance (ANOVA) with event (immediate or normal reappearance) and sex (male or female) as between-subjects factors. No effects were significant: event and sex,  $F(1, 28) < 1.00$ ,  $MSE = 292.86$ ,  $p > .05$ ; interaction,  $F(1, 28) = 2.14$ . This indicates that there were no reliable differences in looking time for infants in the experimental (female,  $M = 36.99$ ,  $SD = 14.74$ ; male,  $M = 33.63$ ,  $SD = 20.50$ ) and control (female,  $M = 26.15$ ,  $SD = 16.89$ ; male,  $M = 40.49$ ,  $SD = 16.08$ ) conditions.

### *Test Trials*

The infants' looking times during the initial and final phases of the test trial were analyzed in the same manner as the pretest trials.

*Initial phase.* The main effects of event and sex were not significant,  $F(1, 28) < 1.00$ ,  $MSE = 3.39$ ,  $p > .05$ . However, the interaction was significant,  $F(1, 28) = 6.42$ ,  $p < .05$ . Analysis of the simple effects of sex at each level of condition suggests that girls' looking times in both the immediate and normal reappearance conditions did not reliably differ (immediate,  $M = 14.99$ ,  $SD = 0.04$ ; normal,  $M = 13.66$ ,  $SD = 2.30$ ),  $F(1, 28) = 2.07$ ,  $p > .05$ . However, boys in the normal reappearance condition tended to look longer than those in the immediate reappearance conditions (immediate,  $M = 12.88$ ,  $SD = 2.87$ ; normal,  $M = 14.85$ ,  $SD = 0.28$ ),  $F(1, 28) = 4.60$ ,  $p < .05$ . Because no significant effects were noted in the final phase, these differences are not discussed further.

*Final phase.* Mean looking times for the final phase of the test event are presented in Table 1. No effects were significant: all effects,  $F(1, 28) < 1.00$ ,  $MSE = 432.62$ ,  $p > .05$ . Infants in the experimental and control conditions looked similarly at the test event (Table 1).

To assess whether the performance of the 4.5-month-olds in Experiment 1 (two-trajectory task) differed reliably from the infants tested by Wilcox and Schweinle (2003, one-trajectory task) the following analyses were conducted. Because of the uneven cell sizes, comparison of the 4.5-month-olds in Experiment 1 ( $n = 16$ ) with the 4.5-month-olds from Wilcox and Schweinle (2003, Experiment 1,  $n = 7$ ) became unwieldy. However, because the performance of the 4.5- and 7.5-month-olds from Wilcox and Schweinle did not differ reliably (Table 1), the

TABLE 1  
 Mean Looking Times During the Final Phase of the Test Event  
 for the 4.5-Month-Olds in This Research and the 4.5- and 7.5-Month-Olds  
 From Wilcox and Schweinle (2003, Experiment 1) Broken Down by Age

	<i>Experiment 1</i>		<i>Wilcox and Schweinle (2003)</i>			
	<i>4.5-Month-Olds<sup>a</sup></i>		<i>4.5-Month-Olds<sup>b</sup></i>		<i>7.5-Month-Olds<sup>b</sup></i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Immediate reappearance	25.39	20.63	34.34	17.79	32.69	15.79
Normal reappearance	28.42	19.60	18.79	13.49	12.40	3.75

<sup>a</sup> $n = 16$ . <sup>b</sup> $n = 7$ .

4.5- and 7.5-month-old data, together ( $n = 14$ ), were compared to that of the 4.5-month-olds from Experiment 1. The data were analyzed via an ANOVA with trajectory (one or two trajectories) and event (immediate or normal reappearance) as between-subjects factors. Means are reported in Table 1. The interaction was significant,  $F(1, 56) = 5.44$ ,  $p < .05$ , indicating that the performance of the infants in Experiment 1 differed reliably from that of the infants from Wilcox and Schweinle. Neither main effect was significant: event,  $F(1, 56) = 2.76$ ,  $MSE = 301.21$ ,  $p > .05$ ; trajectory,  $F(1, 56) = 0.27$ . Comparison of effect sizes for the effect of event from this research (event,  $R^2 = .006$ ; sex,  $R^2 = .0032$ ; interaction,  $R^2 = .0022$ , all small effects) with those from Wilcox and Schweinle ( $R^2 = .14$  for the 4.5- and 7.5-month-olds combined;  $R^2 = .22$  for the 4.5-month-old infants only, a medium effect) support the contention that the infants perform differently with simple rather than complex mapping tasks.

The infants from Wilcox and Schweinle (2003), but not the infants from Experiment 1, looked reliably longer at the one-column display following the immediate rather than the normal reappearance event. These results suggest that only when the occlusion event is very simple (i.e., one-trajectory) are young infants capable of detecting the discrepancy between the immediate reappearance event and the one-object display.

## Discussion

The infants who viewed the immediate and normal reappearance events looked about equally during the final phase of the test event, suggesting that they were unable to detect the discrepancy between the objects seen in the immediate reappearance event and the one-column display. The negative results obtained with the 4.5-month-olds here, where a two-trajectory event-mapping task was used, provide a striking contrast to the positive results obtained with the 4.5-month-olds in Wilcox and Schweinle (2003), where a one-trajectory event-mapping task was

used. Adding a single reversal to the trajectory of the objects was sufficient to impair the 4.5-month-olds' ability to retrieve a clear, coherent representation of the event involving a discontinuity in speed of motion (discontinuity-of-speed event). These results are consistent with other recent reports that seemingly subtle manipulations can influence infants' performance in event-mapping tasks (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002). The next two experiments examined when male and female infants might first succeed at mapping a two-trajectory discontinuous-speed event.

## EXPERIMENT 2

Experiment 2 assessed older, 7.5-month-old, infants' ability to map a two-trajectory discontinuous-speed event. The infants in the experimental condition saw the same immediate and normal reappearance test events as in Experiment 1. Because it is possible that the infants will prefer to look at immediate reappearance events rather than normal reappearance events simply because the occlusion time is shorter or because of other subtle differences in procedures, a control condition was added. The infants in the control condition saw immediate and normal reappearance test events similar to those shown in the experimental condition with one exception: During the final phase of the test trial a second screen stood behind the lowered screen, thereby hiding the area behind it (Figure 1).

We reasoned that if the infants in the experimental condition (a) perceived that two columns were involved in the immediate reappearance event and one column in the normal reappearance event, and (b) found the immediate reappearance event inconsistent with the one-column display, then the immediate reappearance infants should respond with prolonged looking during the final phase of the test trial. Furthermore, if the infants in the control condition (a) also perceived that two columns were involved in the immediate reappearance event and one column was in the normal reappearance event, but (b) recognized that the second column could be hidden behind the shorter screen, then they should look about equally during the final phase of the test event.

### Method

#### *Participants*

Participants were 64 7.5-month-olds ( $M = 7$  months, 13 days; range = 7 months, 3 days–8 months, 7 days). Of those, 32 were male ( $M = 7$  months, 12 days) and 32 were female ( $M = 7$  months, 14 days). An additional 3 infants were eliminated from the analyses: 2 because of procedural error, and 1 because he failed to attend during the initial phase of the test trials. Sixteen infants (8 boys and 8 girls) were

randomly assigned to each of the four groups formed by crossing event (immediate or normal reappearance) and condition (experimental or control): immediate reappearance experimental ( $M = 7$  months, 11 days), immediate reappearance control ( $M = 7$  months, 11 days), normal reappearance experimental ( $M = 7$  months, 14 days), and normal reappearance control ( $M = 7$  months, 14 days).

### *Apparatus*

The apparatus used in Experiment 2 was identical to that of Experiment 1. Two additional screens were constructed for the control conditions. The shorter screen used in the immediate reappearance control condition was 18 cm high and 33 cm wide, and the shorter screen used in the normal reappearance control condition was 18 cm high and 22 cm wide. Both screens were made of cardboard, covered with dark green contact paper, sufficiently tall to hide a second column, and were held upright by a wooden base attached to the floor of the apparatus directly behind the rotating screen.

### *Events*

The pretest and test events in the immediate and normal reappearance experimental conditions were identical to those shown in Experiment 1. The pretest and test events in the immediate and normal reappearance control conditions were identical to the pretest and test events of the immediate and normal reappearance experimental conditions with one exception: During the final phase of the test event the shorter screen occluded the center of the platform.

### *Procedure*

The procedure used in Experiment 2 was identical to that of Experiment 1. The observers were unable to determine which event each infant saw. Interobserver agreement was measured for 50 of the 64 infants and averaged 93.90% per infant.

## Results

### *Pretest Trials*

The infants' mean looking times during the two pretest trials were averaged and analyzed via an ANOVA with event (immediate or normal reappearance), condition (experimental or control), and sex as between-subjects factors. There were no significant main effects or interactions: condition,  $F(1, 56) = 2.81$ ,  $MSE = 253.18$ ,  $p > .05$ ; all other  $F_s(1, 56) < 1.40$ . These results indicate that the looking times of the infants in the four groups did not differ reliably during the pretest trials (immediate reappearance experimental,  $M = 35.09$ ,  $SD = 17.36$ ; normal reappearance ex-

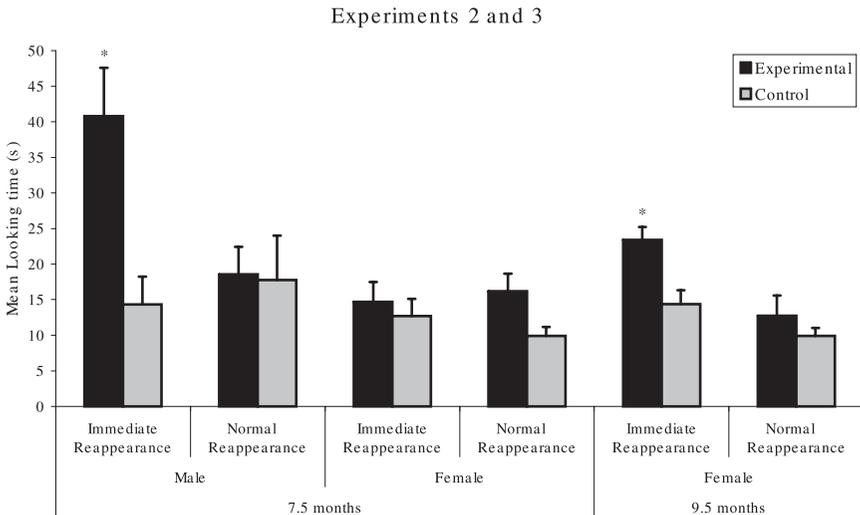
perimental,  $M = 31.82$ ,  $SD = 17.13$ ; immediate reappearance control,  $M = 28.13$ ,  $SD = 17.09$ ; normal reappearance control,  $M = 25.46$ ,  $SD = 11.08$ ).

### Test Trials

The infants' looking times during the initial and final phases of the test trial were analyzed in the same manner as the pretest trials.

**Initial phase.** Neither the main effects of event and sex, nor the interaction, were significant: main effects,  $F(1, 56) < 1.00$ ,  $MSE = 4.35$ ,  $p > .05$ ; interaction,  $F(1, 56) = 1.99$ ,  $p > .05$ . The means were as follows: immediate reappearance experimental,  $M = 13.72$ ,  $SD = 2.11$ ; normal reappearance experimental,  $M = 14.12$ ,  $SD = 1.59$ ; immediate reappearance control,  $M = 13.72$ ,  $SD = 2.63$ ; normal reappearance control,  $M = 13.86$ ,  $SD = 2.05$ .

**Final phase.** The infants' mean looking times during the final phase of the test trial are displayed in Figure 2. The main effects of condition,  $F(1, 56) = 9.21$ ,  $R^2 = .10$ , and sex,  $F(1, 56) = 10.57$ ,  $MSE = 136.98$ ,  $p < .01$ ,  $R^2 = .11$ , were significant and can be explained by examining the Event  $\times$  Condition  $\times$  Sex interaction,  $F(1, 56) = 6.57$ ,  $p < .05$ ,  $R^2 = .07$ . No other effects met significance: event,  $F(1, 56) = 2.96$ ,  $R^2 = .03$ ; Event  $\times$  Condition,  $F(1, 56) = 3.35$ ,  $R^2 = .04$ ; Event  $\times$  Sex,  $F(1, 56) = 2.24$ ,  $R^2 = .02$ ; and Condition  $\times$  Sex,  $F(1, 56) = 2.64$ ,  $R^2 = .03$ , all  $ps > .05$ .



**FIGURE 2** Mean looking times (and standard errors) of the 7.5-month-old boys and girls of Experiment 2, and the 9.5-month-old girls of Experiment 3, during the final phase of the test events.

Upon examination of the three-way interaction, we found that the boys and girls evidenced a different pattern of response to the test events. The Event  $\times$  Condition interaction was significant for boys,  $F(1, 28) = 5.73$ ,  $MSE = 230.72$ ,  $p < .05$ ,  $R^2 = .13$ , but not for girls,  $F(1, 28) = 0.85$ ,  $MSE = 43.25$ ,  $p > .05$ ,  $R^2 = .03$ . Boys in the experimental condition looked reliably longer at the one-column display after having seen the immediate reappearance ( $M = 40.81$ ,  $SD = 19.21$ ) as opposed to the normal reappearance ( $M = 18.55$ ,  $SD = 10.94$ ), protected  $t(28) = 2.93$ ,  $p < .01$ . In the control condition, the boys who saw the immediate appearance ( $M = 14.33$ ,  $SD = 11.06$ ) and normal reappearance ( $M = 17.78$ ,  $SD = 17.66$ ) events looked about equally at the one-column display, protected  $t(28) = 0.45$ ,  $p > .05$ . In contrast, the girls in the experimental (immediate reappearance,  $M = 14.68$ ,  $SD = 7.90$ ; normal reappearance,  $M = 16.16$ ,  $SD = 7.08$ ) and control (immediate reappearance,  $M = 12.69$ ,  $SD = 6.89$ ; normal reappearance,  $M = 9.89$ ,  $SD = 3.59$ ) conditions looked about equally at the one-column display.

The boys in the two experimental conditions of Experiment 2 were also compared to the boys in Experiment 1, resulting in a significant Condition  $\times$  Age interaction,  $F(1, 28) = 5.07$ ,  $MSE = 291.00$ ,  $p < .05$ ,  $R^2 = .14$ . As reported previously, the 7.5-month-olds, but not the 4.5-month-olds, looked significantly longer at the immediate reappearance event than the normal reappearance event. This lends support to the contention that 7.5-month-old boys performed differently than 4.5-month-old boys.

One might be concerned that the positive results obtained with the 7.5-month-old boys in the experimental condition could be explained by perceptual preferences, or other lower level processes, rather than the capacity to compare one event representation to another. There were many differences between the immediate and normal reappearance events: In the immediate reappearance event the objects were occluded for a shorter interval, were in view longer, and moved at a slower pace. It is possible that one or more of these differences led the infants to view the immediate reappearance event as more interesting than the normal reappearance event. Heightened interest to the immediate reappearance event in the initial phase of the test trial could have inflated looking times to the one-column display in the final phase. The negative results obtained in the control condition argue against this explanation, however. If the infants in the experimental condition looked reliably longer following the immediate reappearance event simply because this event piqued their interest, and the increased level of interest continued into the final phase of the test trial, then the infants in the control condition should also have looked longer following the immediate reappearance event. The finding that the boys in the control condition looked about equally following the immediate and normal reappearance events argues against this interpretation. Instead, it supports the interpretation that the male infants in the experimental condition looked longer because they expected to see a second column when the screen was lowered and found the empty area behind the screen unanticipated.

*Additional results.* The sex difference obtained in Experiment 1 suggests that boys, but not girls, can tolerate two trajectories when mapping a discontinuous-speed event. It is possible that once infants can tolerate a single reversal (which creates two trajectories) in an event-mapping task, they can tolerate any number of reversals (i.e., performance changes dramatically with the addition of reversals to an occlusion event, but it does not vary with the number of reversals added). Alternatively, it is possible that number of reversals is an important variable, and that increasing the number of object reversals renders the task increasingly difficult. If this is the case, then boys should perform like girls when additional reversals are added to the discontinuous-speed event. To test this prediction, 12 7.5-month-old boys ( $M = 7$  months, 17 days; range = 7 months, 4 days–8 months, 5 days) were tested in conditions identical to the experimental immediate and normal reappearance conditions of Experiment 1 with one exception: The two-trajectory event seen in the initial phase of the event was repeated before the screen was lowered (i.e., infants saw a four-trajectory immediate or normal reappearance event followed by the one-column display). The results indicated that the infants in the immediate reappearance ( $M = 22.07$ ,  $SD = 11.4$ ) and normal reappearance ( $M = 26.1$ ,  $SD = 21.71$ ) conditions looked about equally at the one-column display,  $F(1, 10) < 1.00$ ,  $MSE = 300.53$ . The boys tested with the four-trajectory task responded like the 4.5-month-old infants and the 7.5-month-old girls tested with the two-trajectory task.

## Discussion

A different pattern of results was obtained for the 7.5-month-old boys and girls in Experiment 2 when a two-trajectory task was used. In the experimental condition, the boys who saw the immediate reappearance event looked reliably longer at the one-column display than did the boys who saw the normal reappearance event. In contrast, the boys in the control condition looked about equally at the one-column display. Further, the 7.5-month-old boys exhibited a reliably different pattern of looking than the 4.5-month-old boys. These results suggest that the 7.5-month-old boys (a) perceived that the immediate reappearance event involved two distinct objects, (b) expected to see two columns on the platform when the screen was lowered, and (c) responded with prolonged looking in the experimental condition when this expectation was violated (in the control condition a second column could have been hidden behind the second, shorter screen).

In contrast to the positive results obtained with the boys, negative results were obtained with the girls. The girls who saw the immediate and normal reappearance events looked about equally at the one-column display, regardless of whether the center of the platform was nonoccluded and empty (experimental condition) or occluded (control condition) during the final phase of the test event. Unlike the boys, the girls were unable to detect a discrepancy between the discontinuous-speed

event and the one-column display. The next experiment explored when girls might demonstrate successful performance in the two-trajectory event-mapping task.

### EXPERIMENT 3

Experiment 3 assessed 9.5-month-old girls' ability to succeed at mapping more complex event sequences using the two-trajectory task of Experiment 2. The infants saw one of two test events (normal or immediate reappearance), and they were tested in one of two conditions (experimental or control).

#### Method

##### *Participants*

Participants were 28 female infants ( $M = 9$  months, 12 days; range = 9 months, 1 day–10 months, 3 days). Seven infants were randomly assigned to each of four groups formed by crossing event (immediate or normal reappearance) and condition (experimental or control): immediate reappearance experimental ( $M = 9$  months, 10 days), immediate reappearance control ( $M = 9$  months, 13 days), normal reappearance experimental ( $M = 9$  months, 12 days), and normal reappearance control ( $M = 9$  months, 11 days).

##### *Apparatus, Events, and Procedure*

The apparatus, events, and procedure were identical to those of Experiment 2. Interobserver agreement was measured for 26 of the 28 infants and averaged 94.15% per infant.

#### Results

##### *Pretest Trials*

The infants' mean looking times during the two pretest trials were averaged and analyzed via an ANOVA with event (immediate or normal reappearance) and condition (experimental or control) as between-subjects factors. There were no significant main effects or interactions, all  $F_s(1, 24) < 1.00$ ,  $MSE = 141.37$ ,  $p > .05$ . These results indicate that the looking times of the infants in the four groups did not differ reliably during the pretest events (immediate reappearance experimental,  $M = 34.04$ ,  $SD = 12.51$ ; normal reappearance experimental,  $M = 30.11$ ,  $SD = 10.65$ ; immediate reappearance control,  $M = 28.74$ ,  $SD = 13.76$ ; normal reappearance control,  $M = 26.49$ ,  $SD = 10.30$ ).

### Test Trials

The infants' looking times during the initial and final phases of the test trial were analyzed in the same manner as the pretest trials.

*Initial phase.* The effect of event was not significant,  $F(1, 24) < 1.00$ , suggesting no large deviations in looking time. The means were as follows: immediate reappearance experimental,  $M = 14.16$ ,  $SD = 1.00$ ; normal reappearance experimental,  $M = 14.50$ ,  $SD = 1.11$ ; immediate reappearance control,  $M = 14.14$ ,  $SD = 1.22$ ; normal reappearance control,  $M = 13.84$ ,  $SD = 1.88$ .

*Final phase.* The infants' mean looking times during the final phase of the test trial are displayed in Figure 2. The main effects of event,  $F(1, 24) = 13.99$ ,  $MSE = 28.58$ ,  $p < .01$ ,  $R^2 = .29$ , and condition,  $F(1, 24) = 8.61$ ,  $p < .01$ ,  $R^2 = .18$ , were significant. Although the Event  $\times$  Condition interaction was not significant,  $F(1, 24) = 2.33$ ,  $p > .05$ ,  $R^2 = .05$ , there was sufficient theoretical and empirical motivation to proceed with the planned comparisons. These comparisons indicated that the infants in the experimental condition looked reliably longer at the one-column display after viewing the immediate reappearance ( $M = 23.40$ ,  $SD = 4.80$ ) as opposed to the normal reappearance ( $M = 12.76$ ,  $SD = 7.53$ ) test event, planned  $t(24) = 3.73$ ,  $p < .01$ . In contrast, the infants in the control condition looked about equally at the one-column display (immediate reappearance,  $M = 14.39$ ,  $SD = 5.11$ ; normal reappearance,  $M = 9.91$ ,  $SD = 2.92$ ), planned  $t(24) = 1.57$ ,  $p > .05$ . Finally, the infants in the immediate reappearance experimental condition looked reliably longer at the final display than the infants in the immediate reappearance control condition, planned  $t(24) = 3.15$ ,  $p < .01$ .

For further support, we compared the infants in the experimental conditions from Experiment 3 to the female infants in the same conditions of Experiment 2. The Condition  $\times$  Age interaction was significant,  $F(1, 26) = 5.64$ ,  $MSE = 48.72$ ,  $p < .05$ ,  $R^2 = .16$ . As reported previously, the 9.5-month-old infants, but not the 7.5-month-old infants, looked reliably longer at the immediate reappearance than the normal reappearance event.

### Discussion

In the experimental condition, the 9.5-month-old girls who saw the immediate reappearance event looked reliably longer at the one-column display than those who saw the normal reappearance event. In contrast, in the control condition, the girls who saw the immediate and normal reappearance events looked about equally at the one-column display. The infants' prolonged looking to the one-object display in the experimental, but not the control, condition suggests that the 9.5-month-old girls in Experiment 3, like the 7.5-month-old boys in Experiment 2, detected the

discrepancy between the discontinuous-speed event and the final one-object display. Additional analysis revealed that the looking times of the 9.5-month-old girls in the experimental conditions of Experiment 3, and those of the 7.5-month-old girls in the experimental conditions of Experiment 2 (who looked equally following the immediate and normal reappearance events), differed reliably. These results suggest that between 7.5 and 9.5 months of age, girls' capacity for mapping discontinuous-speed events improves reliably. The question of why the boys succeeded on this task before the girls is addressed next.

## GENERAL DISCUSSION

These results add to a growing body of literature indicating that event-mapping tasks impose unique information processing demands and, hence, are more than simply a test of infants' capacity to individuate objects. Event-mapping tasks can be used to assess a wide range of representational capacities (e.g., Bonatti, Frot, Zangl, & Mehler, 2002; Leslie et al., 1998; Tremoulet et al., 2001; Wilcox, 2003, 2004; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002; Xu, 2002). The research reported here assessed the effects of event complexity and sex, which are known to influence infants' ability to map events involving different features, on infants' capacity for mapping discontinuous-speed events. Previous experiments conducted by Wilcox and Schweinle (2003) indicated that 4.5-month-olds could successfully map a discontinuous-speed event onto a one-object display when a simple (i.e., one-trajectory) event-mapping task was used. The research reported here built on these findings by investigating 4.5- to 9.5-month-olds' ability to succeed on a slightly more complex (i.e., two-trajectory) event-mapping task. The results indicated a clear developmental progression in infants' capacity for mapping more complex occlusion events. At 4.5 months neither boys nor girls succeeded at mapping a discontinuous-speed event in which the objects followed two trajectories. By 7.5 months, boys, but not girls, demonstrated successful performance, and by 9.5 months, girls also succeeded. Finally, additional results revealed just how fragile infants' capacity for mapping complex occlusion sequences is: When 7.5-month-old boys were tested with a four-trajectory discontinuous-speed event they failed.

Together, these results provide converging evidence for the conclusion that multiple-trajectory tasks are more demanding than single-trajectory tasks, and that girls are more likely to demonstrate impaired mapping performance than boys. These results also raise two questions: First, why does a seemingly minor change in procedure—adding a single reversal to the trajectory of the objects—dramatically alter infants' performance on event-mapping tasks? Second, how do we explain the sex difference in infants' performance? These two questions are addressed in turn.

## Why Multiple Trajectories Impair Event-Mapping Performance

We suggested earlier that there are two ways that event mapping can be accomplished. Infants can (a) retrieve a literal representation of the event and compare that to the final display, or (b) compose a summary representation that contains only the basic elements (i.e., the simple structure) of the event, and compare the summary representation to the final display.<sup>4</sup> We also hypothesized that mapping failures reflect young infants' inability to extract the simple structure of repeating occlusion sequences, making it impossible to form summary representations. As infants' representational capacities improve, they become more skilled at detecting the most important and critical elements of an event. However, there is an alternative explanation that focuses on limitations in short-term or working memory. According to this interpretation, event-mapping failures reflect young infants' inability to maintain complex event sequences in short-term or working memory. As short-term or working memory improves, infants are able to encode and store more information at one time. This allows infants access to literal representations that they previously would not have been able to maintain. Although these data do not distinguish between these two explanations (i.e., improved representational skills or increased memory capacities), recent data obtained by Wilcox (2003) speak to this issue.

Wilcox (2003) examined whether infants' mapping of events involving objects with different features could be facilitated by giving infants information to help them identify the underlying structure of the event. In one experiment, 7.5-month-olds saw a test event in which, first, either a box (box-ball condition) or a ball (ball-ball condition) emerged from behind the left side of a wide screen and returned; second, a ball emerged from behind the right side of the screen and returned. The entire event sequence (box-ball or ball-ball) was repeated. Finally, the screen was lowered to reveal a single ball on the platform. What was novel about this event-mapping experiment was that the infants first saw pretest trials in which the event was deconstructed. For example, in the first pretest trial of the box-ball condition, the box emerged from behind the right side of the screen and returned

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<sup>4</sup>These two accounts rest on the assumption that infants (a) view the initial and final phases of the test trial as distinct events, and (b) attempt to compare their representation of the first event to their representation of the second event. Although there are substantial data to support the idea that infants segregate and compare events, there are alternative interpretations of the data that do not rely on a representational approach. For example, it is possible that infants view the initial and final phases of the test trial as one continuous, ongoing event. According to this interpretation, infants' prolonged looking to the one-object display reflects their capacity to detect inconsistencies in incoming information over time or to recognize changes in the structure of ongoing events. Although these kinds of interpretations differ from our own in the perceptual and cognitive mechanisms that are thought to be involved, the general conclusions are the same: Infants perceive a discontinuous-speed event as inconsistent with the presence of a single object on the platform.

two times. In the second pretest trial, the ball emerged from behind the right side of the screen and returned two times. Hence, each pretest trial contained one component of the event (e.g., a box to the left of the screen or a ball to the right), and both pretest trials, together, formed a complete outline of the upcoming occlusion sequence. The outline, then, specified spatiotemporal patterns of object movement, not the literal movements of the objects but the underlying patterns of motion (e.g., a box emerges to the left of the screen and a ball to the right). Infants were also tested in two control conditions that were identical to the experimental conditions, except that in the pretest trials the objects oscillated to the right or the left of the screen but never moved behind the screen (i.e., the trajectory of the box and the ball were not specified in the pretest trials). The infants in the experimental box-ball condition looked reliably longer at the one-ball display than the infants in the experimental ball-ball condition. In contrast, the infants in the control box-ball and ball-ball conditions looked about equally at the one-ball display. These results suggested that viewing the pretest trials helped infants organize and structure the event in a way that facilitated mapping performance but only when the spatiotemporal coordinates of each object, through occlusion, were specified. That is, viewing the outline helped infants identify the simple structure of the occlusion sequence, which promoted the formation and use of a summary representation.<sup>5</sup> Collectively, these results add to a growing body of evidence indicating that infants have difficulty forming and using representations of complex events involving occluded trajectories (e.g., Arterberry, 1997; Arterberry, Craton, & Yonas, 1993; Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002; Xu, 2002; Xu & Carey, 1996).

### Explaining Sex Differences in Event-Mapping Performance

How do we explain the sex difference in infants' ability to map the discontinuity-of-speed event observed in these experiments? There are at least two possibilities: (a) Boys are better able to remember lengthy event sequences, or (b) boys are

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<sup>5</sup>One could argue that viewing the ball and the box in the pretest trials simply boosted memory for the objects, and the side of the screen to which they would be seen, in the test trials. There are two reasons to doubt such an explanation, however. First, the infants in the control condition, where the ball and the box oscillated next to the screen in the pretest trials, did not demonstrate success, suggesting that additional exposure to the objects was not sufficient to support mapping performance. Second, it is difficult to imagine how the pretest trials could have led to improved memory for the repeating occlusion sequence because the pretest events, seen in sequence, did not make up a literal and complete test event. Consider the box-ball event. In each pretest trial the object, first the box and then the ball, emerged twice to each side of the screen. Combining the two pretest trials, in their literal form, would create an event in which the box emerged twice to each side of the screen and then the ball emerged twice to each side of the screen. However, in the test event, the box and the ball emerged once to each side of the screen, and then this entire sequence was repeated.

more skilled at extracting the simple structure of complex events. Of these two possibilities, we support the latter, for several reasons. First, evidence presented in the preceding sections suggests that differences in event-mapping performance are better explained by the capacity to identify the simple structure of occlusion sequences than by limitations in short-term or working memory. Second, when sex differences in short-term or working memory in infants are observed they typically favor girls rather than boys (e.g., Creighton, 1984; Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997; Overman, Bachevalier, Schuhmann, & Ryan, 1996; Tighe & Powlison, 1978). Third, recent data reported by Wilcox (2003) supports the idea that boys are more likely than girls to extract the simple structure of occlusion sequences. For example, in one experiment, 7.5-month-olds were tested in box-ball and ball-ball conditions identical to the experimental box-ball and ball-ball conditions described previously with one difference: In the pretest trials the ball and box emerged only once to each side of the screen. Hence, the infants received less explicit information about the simple structure of the event. In this experiment, the boys in the box-ball condition looked reliably longer at the final one-ball display than those in the ball-ball condition; in contrast, the girls in the two conditions looked about equally at the final display. These results suggested that the girls were less likely to identify the simple structure of the occlusion sequence when the event outline was less explicit.

What is the basis for this sex difference? There have been a number of sex differences reported in infants' perception of visual stimuli or events, some favoring boys (e.g., Overman et al., 1997; Overman et al., 1996; but see Diamond, 1985) and some favoring girls (e.g., Bauer, Shimojo, Gwiazda, & Held, 1986; Creighton, 1984; Held, Shimojo, & Gwiazda, 1984; Overman et al., 1997; Overman et al., 1996; Tighe & Powlison, 1978). Although the tasks that have previously revealed sex differences favoring boys differ from the event-mapping tasks of Wilcox and her colleagues (e.g., Wilcox, 1999, 2003, 2004; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Schweinle, 2002, 2003) in many ways, making it difficult to draw firm conclusions about the basis for the differences observed, loose parallels can be drawn. Perhaps the most pertinent to this discussion are findings that human (Overman et al., 1997; Overman et al., 1996) and monkey (Clark & Goldman-Rakic, 1989; Goldman, Crawford, Stokes, Galkin, & Rosvold, 1974) male infants mature more quickly in their ability to perform on tasks that require them to keep track of trial-to-trial changes in contingencies, to retrieve and act on stored information, and to relate information over space and time. For example, male infants are more likely than female infants to succeed on an object reversal task (i.e., participants must learn to choose a new or unrewarded object over a previously rewarded object). Furthermore, these differences have been linked to different rates of cortical maturation that appear to be hormonally induced (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Hagger & Bachevalier, 1991; Hagger, Bachevalier, & Bercu, 1987). For example, research with monkeys sug-

gests that the orbital frontal lobe mediates tasks that require spatiotemporal integration of information, that the orbital frontal lobe matures more quickly in males, and that altering the level of plasma testosterone alters performance on tasks that tap orbital frontal functions (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Goldman et al., 1974).

Together, these results suggest a possible biological basis for the sex difference obtained in these experiments. The cognitive processing required in the discontinuous-speed event-mapping task is similar, in some respects, to the cognitive processing required by tasks known to be mediated by the orbital frontal cortex. For example, success on the discontinuous-speed event-mapping task is dependent on infants' ability, first, to integrate motion-carried information through an occlusion sequence, and second, to track information about the identity of objects across successive, and categorically distinct, events. Both of these processes require updating and integration of information over space and time. Of course, this account is only speculative and the mechanisms involved are probably more complex than described here. For example, hormonally induced changes in the orbital frontal lobe could be triggered by biological events or select environmental experiences. In addition, it is unclear what kinds of experiences would lead to such pronounced differences in behavior at 7.5 months. Finally, it is unknown how, or if, these early sexually dimorphic cognitive behaviors are related to sex differences in cognitive functioning that have been reported in older children and adults. These important questions will be the topic of future research.

## SUMMARY AND CONCLUDING REMARKS

This research adds an important piece to a growing body of research on infants' capacity to represent and map occlusion sequences. The current research, when combined with previous research, specifies a clear developmental progression in infants' event-mapping capabilities. This developmental progression can be summarized in the following way: When infants can use spatiotemporal criteria to individuate objects, they succeed at mapping simple (i.e., one-trajectory) events at 4.5 months (boys and girls) and complex (i.e., two-trajectory) events at 7.5 months (boys) and 9.5 months (girls). When infants must use featural criteria to individuate objects, they first succeed at mapping simple events at 5.5 months (boys and girls) and complex events at 10.5 months (boys) and 11.5 months (girls). Together, these findings suggest two important conclusions. First, when infants can use spatiotemporal information to individuate the objects the simple structure is clearer, promoting mapping success. In contrast, when featural criteria must be used to individuate the objects, it is more difficult for infants to extract the simple structure of the event, adversely affecting mapping performance. Second, boys typically perform better on multiple-trajectory tasks than girls, perhaps because of

sexually dimorphic rates of maturation in the frontal lobe, an area thought to mediate cognitive functions that support mapping performance.

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